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NATURAL FIBRES REINFORCED GYPSUM COMPOSITES

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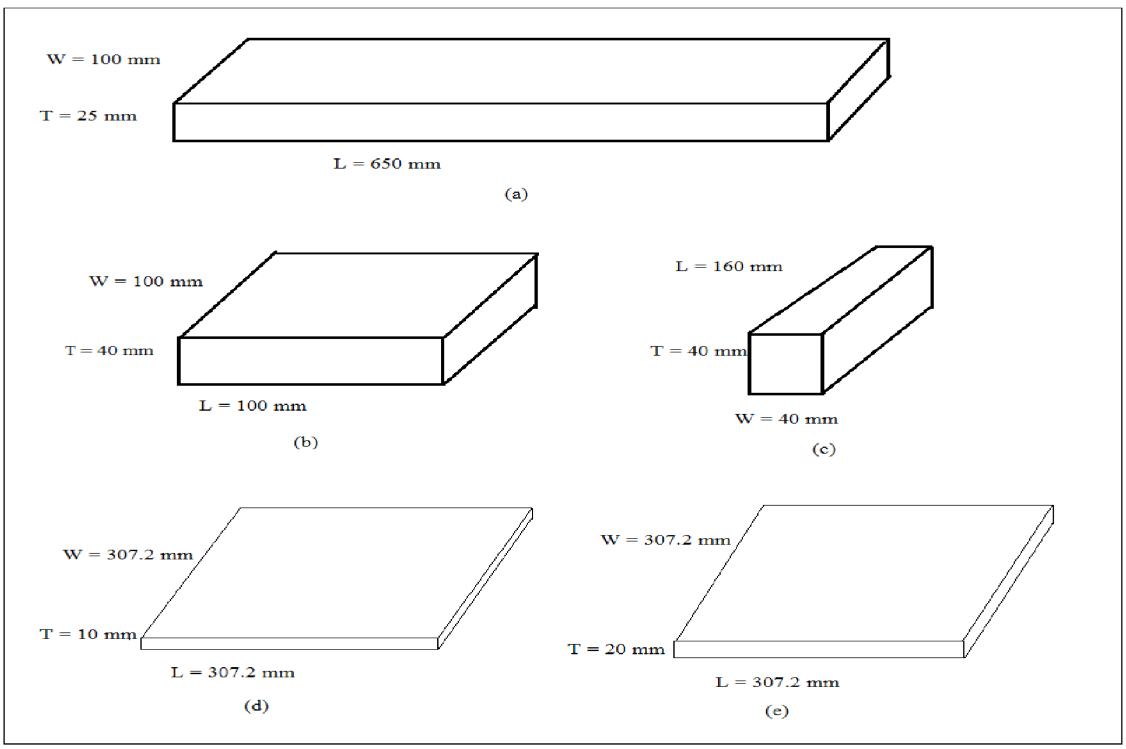
ABSTRACT
This paper describes an investigation on the use of a new composite construction material composed of gypsum and natural fibers, having some properties potentially useful in technical domains. Thermal insulation and some mechanical properties and physical properties are investigated. The results showed that the incorporated natural fibres changed the rheological and mechanical behavior of the material and increase considerably its ductility and cracking threshold. A decrease in thermal conductivity and bulk density is recorded. Therefore, it seems to be a promising composite for saving energy suitable for extreme climatic places.

KEYWORDS: Natural fibres, Flexural strength, Compressive strength, Thermal insulation, Moisture Content, Density,

INTRODUCTION
Due to its availability in the subsoil, relative low cost, ease of high usage and mechanical characteristics suitable for many uses, plaster is a widely used construction material. A number of studies have shown that synthetic fibres reinforced plaster materials possess a best mechanical efficiency, but the increase in cost and its effect on the environment due to this kind of fibres have forced scientists and engineers to synthesize new materials of low cost and renewable resources, and environmentally friendly, like natural fibres because there are less gluttonous in fossil energy. Concerning the mechanical properties of the fibers noted that the compressive strength and the thermal conductivity decreased with the increase of the dosage of a composite reinforced with natural fibers. Some of the studies have shown that all the mechanical properties decrease with percentage of polyamide fibres reinforced plaster except the fracture toughness. In the present study, taking into account the parameter related to fibres, such as, their proportions and their geometries on the mechanical effectiveness after hardening, we attempted to study the influence of the percentage by weight and the properties of plaster. The mechanical, thermal and physical properties obtained from the experiments were compared with theoretical evaluations.



EXPERIMENTAL METHODS

Materials

The plaster used in this study is industrial stucco plaster used as finishing material. Its major constituent is CaSO4.2H2O. The fibres used in this study are natural fibres selected are coir, jute, banana fibre, cotton and wool. Out of which coir, jute and banana fibres were given a hot water treatment to remove excess wax and lignin content. Where cotton fiber is scoured to increase its absorbency and raw wool is extracted from sheep and given a softening treatment with sodium bicarbonate and detergent. The fibre length is kept between 20-40 mm and proportion of the fibres are varied from 0 to 3% on dry weight of gypsum.

Mix Designs

The mix design optimization was developed with fibre dispersion method. Gypsum and fibres were mixed in dry state and then water is poured and mixed thoroughly to make stable dispersion. Then the mixture is poured into the molds to make composites. The gypsum and water ratio is kept the same to maintain its viscosity. Initial samples were made with 0% fibres. Gradually each fibre with different proportions is mixed and samples were made. The samples were made as per BS 5669: part 1 for particle boards [4,5]. The prepared sizes of mold are with a size of 650 mm (length) x 100 mm (width) x 25 mm (thickness) for bending test, the size of 100 mm x 100 mm x 40 mm for density, moisture content and absorption, and the size of 160 mm x 40 mm x 40 mm of compression and the size of 307.2 mm x 307.2 mm x 10 mm of thermal insulation as shown in figure 1.

Testing Methods

Testing of Fibre Reinforced Gypsum Composites

Five characteristics of fibre reinforced gypsum composites were tested. The details of testing done on composites are as mentioned in table 1.

Table 1 Composite testing instruments and methods

S.No	Parameters	Instrument/Methods
1	Compressive Strength	Compressive Strength Tester
2	Flexural Strength	Flexural Strength Tester
3	Thermal Insulation	Sample House Method
4	Moisture Content	Oven Dry method
5	Density	Weight/Volume method

Compressive Strength

Forty eight (48) numbers of specimens were prepared for compressive strength test in a size of 160 mm x 40 mm x 40 mm in order to have a cuboids size according to the procedure specified in BS5669: Part 4 [4,5]. The controlled specimen and specimen with fiber content are tested. The specimen was tested for compressive strength parallel to the plane of the board by applying increasing compressive load until failure occurs. Thus, the reading of the maximum load for failure can be obtained.

The calculation for compressive strength is obtained from the following equation:

$$K_p = W/A$$

Where,

K_p = compressive strength (in N/mm^2)

W = the maximum load applied to the test specimen (in N)

A = the cross section of the test specimen (in mm^2)

Flexural Strength

Forty eight (48) specimens with the size of 650 mm in length, 100 mm in width and 25 mm in thickness was tested for flexural behavior. Thickness and length were selected to accommodate the requirement of testing method in BS 5669: Part 1 [4,5] and also the capacity of the testing machine. Observation and comparison on the strength were made between the controlled specimen and the specimen with different fiber content.

The length between the supports was taken as 625 mm for all of the specimens. The load was applied perpendicular to the plane of the board. The machine was applied with 0.02 kN/s load pace until fracture occurred and the maximum load readings were taken from the machine initial screen.

The bending strength, P (N/mm^2) was calculated and expressed to the nearest 1 N/mm^2 using the following equation:

$$P = FL/Wd^2$$

Where,

F = the maximum applied load to the test specimen (in N)

L = span between the center of the supports (in mm)

W = width of the test specimen (in mm)

d = mean thickness of the test specimen (in mm)

Thermal Insulation

Forty eight (48) samples were made with dimension of flat sheet was 12”x12”x10mm. Thermal insulation is the reduction of heat transfer between objects in thermal contact or in range of radiative influence. Thermal insulation can be achieved with specially engineered methods or processes, as well as with suitable object shapes and materials. Heat flow is an inevitable consequence of contact between objects of differing temperature. Thermal insulation provides a region of insulation in which thermal conduction is reduced or thermal radiation is reflected rather than absorbed by the lower-temperature body.

Sample houses with brick work of the same height and width are made; the composite sheet is used as roof to evaluate the temperature difference, between atmospheric temperature and the temperature inside the houses. Thermometers are kept in the houses and temperature is recorded hourly from 10 am to 5 pm.

Moisture Content and Density

Ninety six (96) samples were prepared for both moisture content and density. Same size of specimen was used for moisture content and density. The size of the specimen used is 100 mm x 100 mm x 40 mm as shown in Figure 1. The size was selected based on the criteria set in BS 5669: Part 1 [4,5]. For moisture content, the specimen was required to be placed in circulating oven, at temperature of 103 ^{o}C ± 2 ^{o}C, cooled, weighed and recorded the mass. Density is calculated by direct method (weight/volume).

RESULTS AND DISCUSSION

Introduction

The experimentation of this work was conducted as per the plan of work shown. The fibre reinforced gypsum composites were tested for five parameters namely compressive strength, flexural strength, thermal insulation, moisture content and density.

Effect of fibre reinforcement on Compressive Strength of gypsum composites.

The compressive strength readings are shown in table 2. There is a significant difference between the compressive strength value between different proportions of fibers as well as between fibers. Compressive strength is the capacity of a material or structure to withstand axially directed pushing force. It provides data of force verses deformation for the test method. When the limit of compressive strength is reached brittle materials are crushed. Compressive strength is measured using the Universal testing machine.

For estimating compressive strength of gypsum composites, as discussed earlier the volume fraction was varied from 0%, 1%, 2%, and 3.00% on weight of gypsum. Five different types of fibers were used viz. banana fiber, coir, jute, wool and cotton were used. The related compressive strength readings in N/mm^2 are as given in table 2, where each reading specifies average of 3 readings.

Table 2 Observations of Fiber reinforced gypsum composites for Compression strength

	0 %	1 %	2 %	3 %
Without fibre reinforcement	9.63	-	-	-
Coir	-	6.44	5.63	4.00
Jute	-	5.38	4.56	3.25
Banana	-	6.69	3.88	1.43
Cotton	-	4.06	4.50	5.00
Wool	-	7.06	5.38	4.44

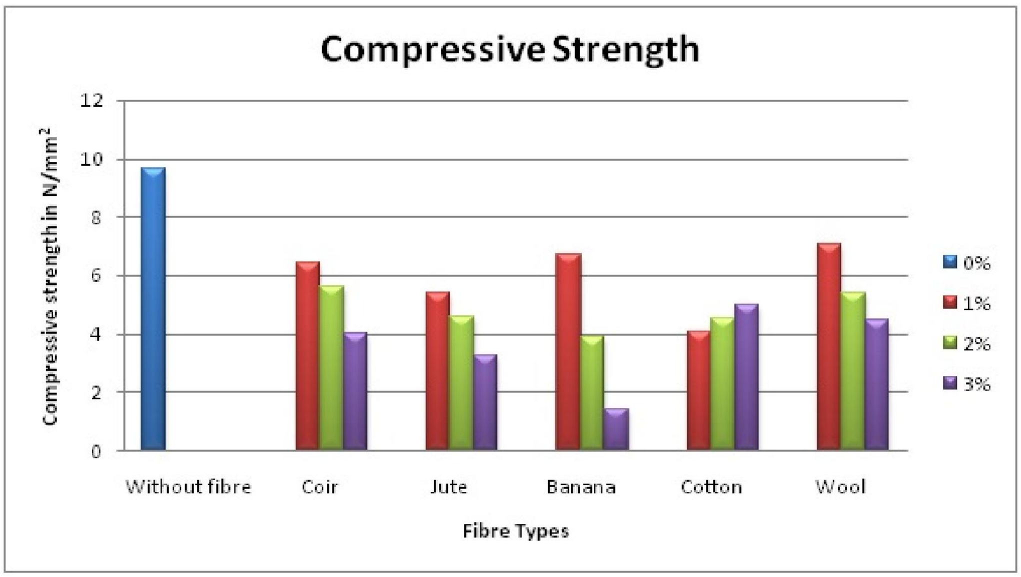


Figure 2 Effects of fibre type and proportion on compressive strength

The figure 2 shows the graphical presentation of compressive strength readings with different fibre content in the composites. On 'X' axis different fibres were plotted and on 'Y' axis compressive strength readings in N/mm^2 were plotted. From figure it can be observed that within the same fiber as the fiber content increases there is a significant effect on the compressive strength readings which indicates that as the fiber content increases from 0 to 3.00% there is an adverse effect on compressive strength of composites.

The different types of fibers when studied together for each fiber content it was found that there is a significant effect on compressive strength of composites, as the fiber percentage increased the compressive strength decreased drastically i.e. coir, banana fiber, jute, wool. Whereas cotton showed a gradual increase in compressive strength as the percentage increased from 1 to 3 %. As the fiber proportion increased there was a gradual decrease in density. Due to lack of adhesion of fibre and gypsum surface there is a decrease of compressive strength except cotton which showed a gradual increase in compressive strength as fibre percentage increased but lesser than controlled specimen, due more area available for adhesion. This limitation can be reduced by using a binder feasible with both the materials in future work.

Effect of fiber reinforcement on flexural strength of gypsum composites

The flexural strength readings are as shown in table 3. There is a significant difference in the flexural strength value between different proportions of the fibers as well as between the fibers. Flexural strength is also known as modulus of rupture, bend strength or fracture strength. A mechanical parameter for a brittle material is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently used in which a specimen having a rectangular cross section is bent until fracture using a four point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture.

For estimating flexural strength of composite, as discussed earlier the volume fraction was varied from 0%, 1%, 2%, and 3.00% on weight of gypsum. Five different types of fibers were used viz. banana fiber, coir, jute, wool and cotton were used. The related flexural strength readings are as given in table 3, where each reading specifies average of 3 readings.

Table 3 Observations of Fiber reinforced gypsum composites for Flexural Strength

Fibre Content	0 %	1 %	2 %	3 %
Without fibre reinforcement	2.9	-	-	-
Coir	-	0.8	1.1	1.6
Jute	-	1.8	2.2	2.5
Banana	-	0.9	1.4	2.0
Cotton	-	2.5	2.5	2.6
Wool	-	2.5	2.6	2.8

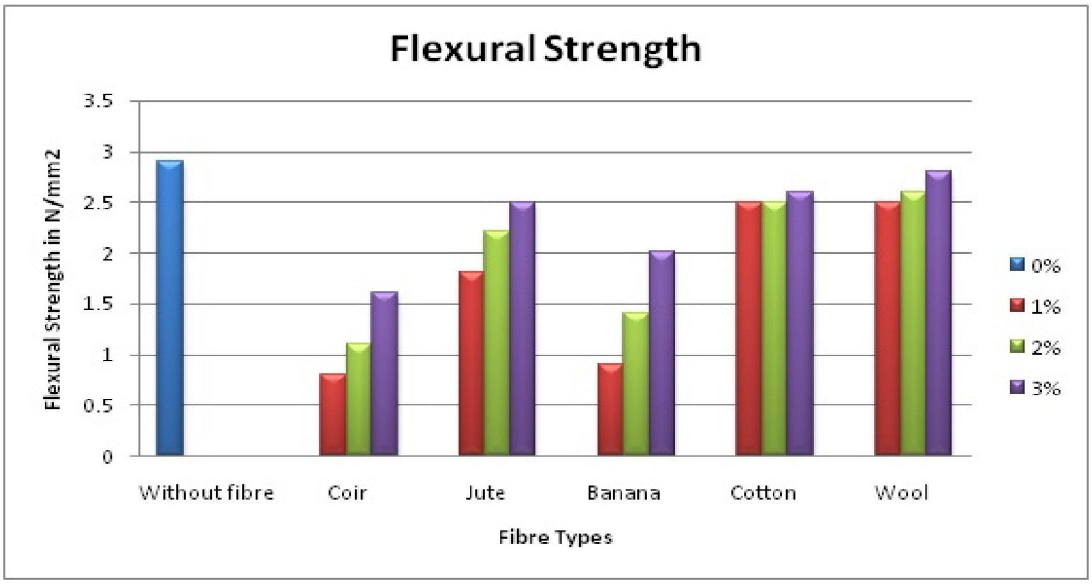


Figure 3 Effects of fibre type and proportion on flexural strength

The figure 3 shows the graphical presentation of flexural strength readings with different fibre content in the composites. On 'X' axis different fibres were plotted and on 'Y' axis flexural strength readings in N/mm^2 were plotted. From figure it can be observed that within the same fiber as the fiber content increases there is a significant effect on the flexural strength readings which indicates that as the fiber content increases from 1 to 3.00% there is gradual increase in flexural strength of composites but lesser than controlled specimen.

As the fiber proportion increased there was a gradual increase in flexural strength. Due to lack of adhesion of fibre and gypsum surface there is very less weight transfer from matrix to reinforcement. This limitation can be reduced by using a binder feasible with both the materials.

Effect of fibre reinforcement on Thermal Insulation of composites

The thermal insulation readings are as shown in table 4. There is a significant difference in the thermal insulation value between different proportions of the fibers as well as between the fibers.

For estimating thermal insulation of composite, as discussed earlier the volume fraction was varied from 0%, 1%, 2%, and 3.00% on weight of gypsum. Five different types of fibers viz. banana fiber, coir, jute, wool and cotton were used. The related thermal insulation readings are as given in table 4.

Table 4 Observations of Fiber reinforced gypsum composites for Thermal Insulation

Time	Fibre %	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
Atm.Temp		**35**	**36**	**38.5**	**40**	**40**	**41.5**	**40**	**38**
	0%	34	35	37	38	38	39	38	37
Coir	**1.00%**	33.5	34	35.5	37.5	37.5	38	37.5	36.5
	2.00%	33	33.5	35	36.5	36.5	37	36.5	36
	3.00%	32	33	34	36	36	36.5	36	35

Jute	**1.00%**	33	33.5	35.5	36	36	38	38.5	35.5
	2.00%	32.5	33	35	35	35.5	37	37	35
	3.00%	32	32.5	34	34.5	35	36	36	34
Banana fibres	**1.00%**	34	35	36.5	37	37.5	38	37	36
	2.00%	33.5	34.5	36	36	37	37	36	35.5
	3.00%	33	34	35	35	36	36.5	35.5	35
Cotton	**1.00%**	33	33.5	34	35	35.5	36	36	35
	2.00%	32	32.5	33	34	34.5	35	35	34
	3.00%	31	31.5	32	33	33.5	34	34	33
Wool	**1.00%**	34	34	36	38	38	38.5	38	36.5
	2.00%	33.5	33.5	35.5	37	37	37.5	37	35.5
	3.00%	33	33	35	36	36	37	36	35

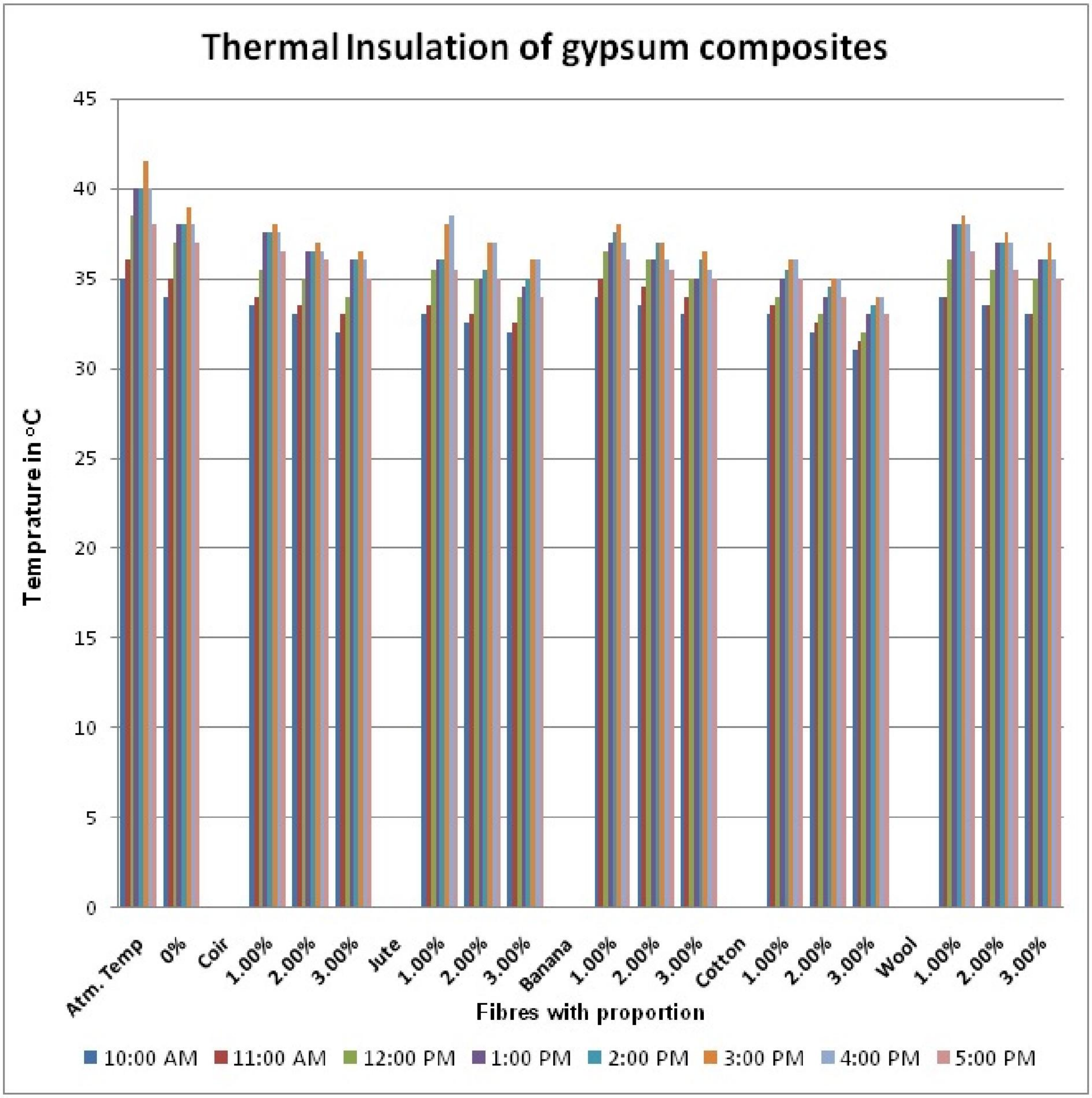


Figure 4 Effects of fibre reinforcement on thermal insulation

The figure 4 shows the graphical presentation of thermal insulation readings with different fiber content in the composites. On 'X' axis different fibres were plotted and on 'Y' axis thermal insulation readings in ^{o}C were plotted. From figure it can be observed that within the same fiber as the fiber content increases there is a significant effect on the thermal insulation readings which indicates that as the fiber content increases from 1 to 3.00% there is gradual increase in thermal insulation of composites. The different types of fibers when studied together, it was found that there is a significant effect on thermal insulation of composite, as the fiber percentage increased the thermal insulation increased gradually.

As the fiber proportion increased there was a gradual increase in thermal insulation. Fibers act as barriers to the movement of electrons resulting in slowing down in its velocity, which takes higher time to pass through the surface.

Effect of fibre reinforcement on Moisture Content of Composites

The moisture content readings are as shown in table 5, where each reading specifies average of 3 readings. There is a significant difference in the moisture content value between different proportions of the fibers as well as between the fibers.

For estimating moisture content of composite, as discussed earlier the volume fraction was varied from 0%, 1%, 2%, and 3.00% on weight of gypsum. Five different types of fibers viz. banana fiber, coir, jute, wool and cotton were used. The size of the specimen used is 100 mm x 100 mm x 40 mm as shown in Figure 1. The size was selected based on the criteria set in BS 5669: Part 1 [4,5]. For moisture content, the specimen was required to be placed in air circulating oven, at temperature of 103 ^{o}C ± 2 ^{o}C, cooled, weighed and recorded the mass. The moisture content readings are as given in table 5.

Table 5 Observations of Fiber reinforced gypsum composites for Moisture Content

Types of fibres	0%	1%	2%	3%
Without fibre	0.48	-	-	-
Coir	-	0.83	0.94	1.22
Jute	-	1.00	1.46	1.62
Banana fibres	-	0.69	0.97	1.10
Cotton	-	0.55	0.62	0.81
Wool	-	0.84	1.06	1.57

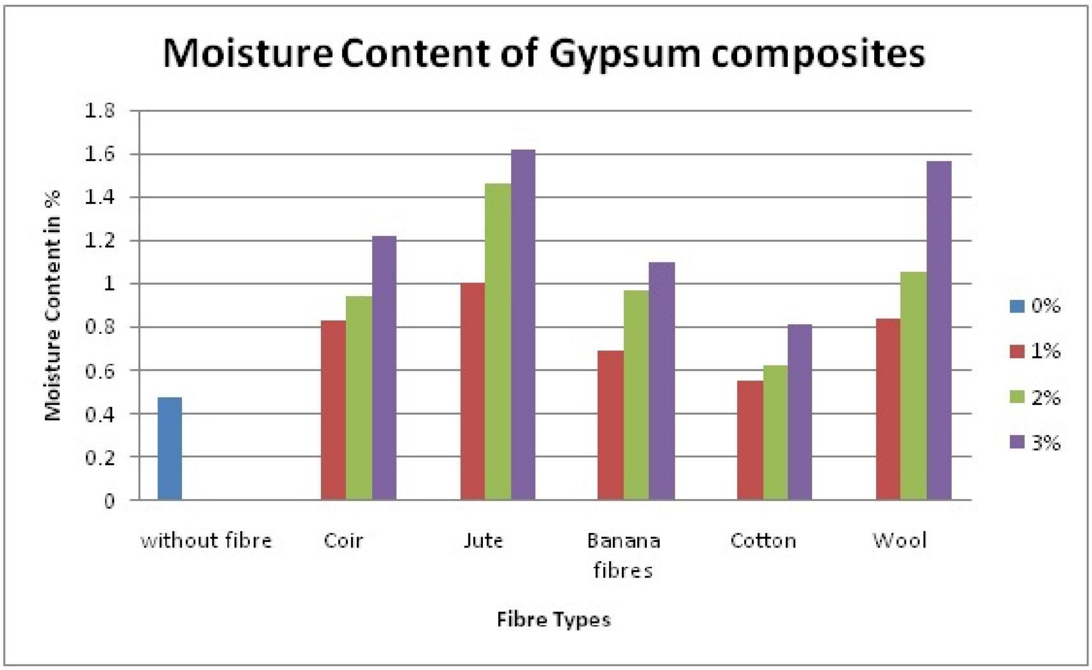


Figure 5 Effects of fibre reinforcement on moisture content of gypsum composites

The figure 5 shows the graphical presentation of moisture content readings with different fiber content in the composites. On 'X' axis different fibres were plotted and on 'Y' axis moisture content readings in % were plotted. From figure it can be observed that within the same fiber as the fiber content increases there is a significant effect on the moisture content readings which indicates that as the fiber content increases from 1 to 3.00% there is gradual increase in moisture content of composites.

The different types of fibers when studied together, it was found that there is a significant effect on the moisture content of composite, as the fiber percentage increased the moisture content increased gradually.

As fibres used in this study are hygroscopic in nature they tend to absorb moisture quickly and the pores in composites tend to absorb moisture. From the figure it can be observed that moisture has not increased more than 2 % which can be considered as under controlled one.

Effect of fibre reinforcement on density of gypsum composites

The density readings are as shown in table 6. There is a significant difference in the density value between different proportions of the fibers as well as between the fibers.

For estimating density of the composite, as discussed earlier, the volume fraction was varied from 0%, 1%, 2%, and 3.00% of weight of gypsum. Five different types of fibers viz. banana fiber, coir, jute, wool and cotton were used. The size of the specimen used is 100 mm x 100 mm x 40 mm as shown in Figure 1. The size was selected based on the criteria set in BS 5669: Part 1 [4,5]. For density, the specimens were required to be weighed and recorded the mass and divide it by its volume. The related density readings are as given in table 6.

Table 6 Observations of Fiber reinforced gypsum composites for Density

Types of fibres	0%	1%	2%	3%
without fibre	1.46	-	-	-
Coir	-	1.32	1.22	1.15
Jute	-	1.05	1.02	0.95
Banana fibres	-	1.37	1.26	1.18
Cotton	-	1.05	1.01	0.98
Wool	-	1.01	1.00	0.97

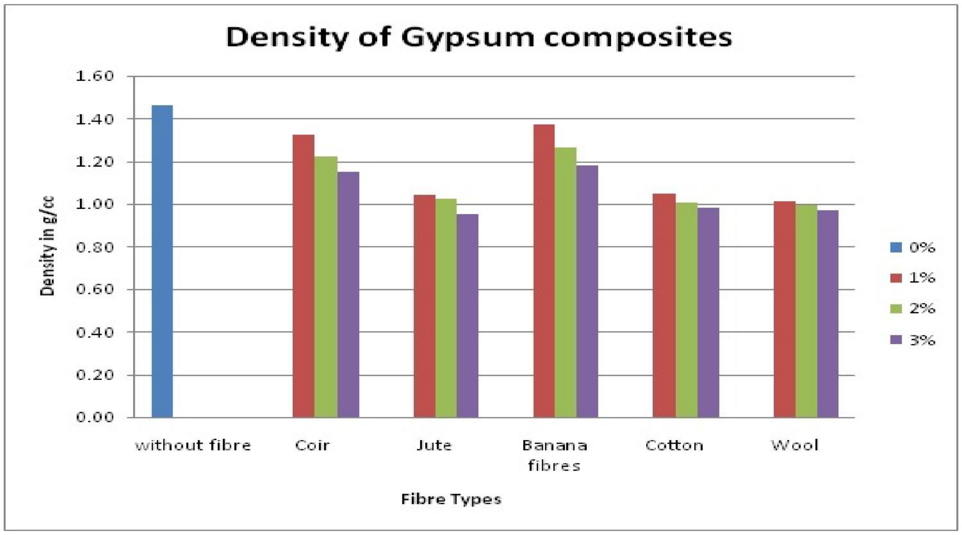


Figure 6 Effect of fibre reinforcement on density of gypsum composites

The figure 6 shows the graphical presentation of density readings with different fiber content in the composites. On 'X' axis different fibres were plotted and on 'Y' axis density readings in grams/cc were plotted. From figure it can be observed that within the same fiber as the fiber content increases there is a significant effect on the density readings which indicates that as the fiber content increases from 1 to 3.00% there is a gradual decrease in density of composites.

The different types of fibers when studied together, it was found that there is a significant effect on the density of the composite, as the fiber percentage increased the density decreased gradually, since specific weight of gypsum is more than that of fibres.

CONCLUSION

From this extensive experimental study, the effect of fiber volume fraction on moisture content, properties such as compressive strength, flexural performance, thermal insulation, moisture content and density have been ascertained and discussed. The compressive strength properties have shown a decline as the density decreases compressive strength decreases. Flexural strength initially shown a decline and since then as fibre proportion increased it tend to increase as better weight transfer from matrix to reinforcement has occurred. Thermal insulation has shown a promising opportunity for fibre reinforcement has attained good insulation value to the composites. Moisture content has not been affected much with fibre reinforcement. Density has decreased as fibre volume fraction increased which will make it a better material with less weight and good performance as false ceiling tile and non load bearing wall partitioning.

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